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INCIDENCE AND EFFECTS OF WHITE PINE BLISTER RUST IN PLANTATIONS WITH SUGAR PINE IN THE NORTHERN AND CENTRAL SIERRA NEVADA

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ABSTRACT

The incidence and severity of white pine blister rust has increased dramatically during the past 10 years in the Sierra Nevada forests. Twenty-nine plantations with sugar pine were surveyed in the northern and central Sierra Nevada to determine the incidence of blister rust. All but one were infested by the disease. Infection levels ranged from 44 to 93% of the stems, with an overall average of 69%. The majority of these infections were classified as being lethal. The age of the plantation influenced the proportion of trees in different infection classes. Younger plantations had larger proportions of either dead or uninfected trees. The proportion of living infected trees increased with plantation age as the proportion of dead or uninfected trees decreased. The present level of blister rust was projected to reduce the stocking below acceptable levels in 4 plantations. An additional 7 plantations will have their currently unacceptable stocking reduced further by the disease. No relationship between the incidence of rust and estimated site hazard was found.

INTRODUCTION

White pine blister rust, caused by Cronartium ribicola, has had an increasingly adverse impact on the management of western white pines for the past 75 years. For almost 60 years, the disease has been spreading throughout the range of sugar pine in northern California. Forest Pest Management surveys in 1982 and 1983 on the Sierra and Sequoia National Forests extended the southern limit of the disease and found increasing incidence and intensification of the disease

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in natural stands (reference Forest Pest Management Report No. 82-44, December 13, 1982 and Report No. 84-22, May 14, 1984). Direction at that time was that sugar pine could be managed as a commercial species if the presence and intensity of blister rust were considered in management plans. Increased activity in identifying rust resistant trees and their propagation would be necessary for many areas, however.

Since these surveys, the disease has been observed with increasing frequency. Blister rust has been identified in new infection centers and has increased in intensity where already present. These observations included infections on sugar pine and western white pine at higher elevations. The importance of this increase is being recognized on Forests in the central and southern Sierra Nevada where sugar pine has been a significant species for regeneration. Also, the disease is being found and recognized as a potential management constraint on what were once considered low hazard sites in the central and northern Sierra Nevada.

These observations and concerns resulted in questions about the effects of blister rust on the viability of sugar pine as a future commercial species in intensively managed plantations. Because of the variety of sites from which blister rust was reported, our ability to define and recognize different levels of site hazard was questioned. Forest Pest Management initiated a survey of plantations with sugar pine in the northern and central Sierra Nevada to begin to answer these questions and to document observations and reports from the field.

The following were the objectives of the survey.

1. To determine the proportion of sugar pines infected by blister rust in a sample of 5- to 25-year-old plantations on the Plumas, Tahoe, Eldorado, and Stanislaus National Forests.

2. To determine the proportion of trees lethally infected by blister rust in each of the above plantations.

3. To determine the accuracy of the FPM rust hazard rating system and its effectiveness in predicting survival of sugar pine to a merchantable size.

METHODS

Information on plantations with sugar pine were obtained from Forest and District Silviculturists from each of the above named Forests. Requirements for selecting potential candidates were that they should be 5 to 25 years of age, have at least 10 percent sugar pine stocking, and preferably be on low hazard sites. These sites were defined as being ridge tops and southerly aspects away from stream bottoms. Selections were to be made without regard to the known presence or absence of blister rust.

Plantations submitted were screened to see if they fit the criteria. Plantation age was expanded to 4 to 26 years to broaden the distribution. Plantations were randomly selected independently from each Forest's submission

to ensure a north-south distribution. The number of plantations selected for each Forest varied depending on the size of the sample submitted.

Prior to initiating the survey of each plantation, observations of surrounding stands were made to detect the presence of blister rust. Impressions of the site's rust hazard potential were noted. The plantation was then systematically sampled. The starting point of the sample was determined by pacing 3 to 5 chains (198 to 330 feet) from a corner of the plantation previously selected on a stand map. The direction of the transect was predetermined and attempted to have the transect cross the topographic gradient. The sampling unit was a 1/2-chain wide (33 feet) strip centered on the transect line. Total transect length for the plantation was measured to determine area sampled. Blister rust infection data were collected on each sugar pine in the sampling unit. Each sugar pine received one of the following five infection rating classes: healthy, no infections; non-lethal infections ($\geq$ 24 inches from bole); lethal infection ($<$ 24 inches from bole and bole infections); dead - blister rust; dead - other causes. If more than one rating was possible, then the most severe rating was given.

At 10 chain (660 feet) intervals along the transect, a plot 1/2-chain on a side (0.025 ac) was established. In addition to the above information, the following data were collected: number of trees by species, number of Ribes plants up to 4 per plot, and the site hazard rating. Site hazard ratings were based on vegetation and site information that had been developed during the blister control work of the 1960s (reference Blister Rust Control Handbook, California Region, 1956) and from FPM perceptions of the biology of the disease.

When the transect reached the boundary of the plantation, the return transect was begun 3 to 10 chains along the boundary. The distance between transects was determined by the size of the plantation. Data were only collected within the plantation's boundary. Transects were continued until either the plantation was completely surveyed, 300 sugar pines were tallyed, or 20 plots were recorded.

RESULTS

A total of 29 plantations and 4323 sugar pines were sampled on the four National Forests (Table 1). They varied widely in size and their ages were distributed within the range desired. Most of the sites were south or west facing and on the upper slope or on ridge tops. Slopes were minimal to moderate.

Of the 29 plantations surveyed, all but one were infested by white pine blister rust (Figure 1). Infection levels in the 28 plantations with blister rust ranged from 44 to 93%. A north to south gradient of infection was not observed. Average infection levels for each Forest were: Plumas - 61%; Tahoe - 72%; Eldorado - 71%; and Stanislaus - 72%. The majority of infected trees had lethal infections (Figure 2). All dead trees had been killed by blister rust. The proportions of trees infected for each infection rating class are presented in Table 2.

The proportion of trees in each rating class varied with plantation age (Figure 3). Younger plantations generally had more trees that had either been killed -r were uninfected. With plantation age, the proportion of trees that had died decreased, as did the number of uninfected trees. The proportion of living infected trees increased, although the proportion of non-lethal infections was still a minor component.

Stocking levels were highly variable, with 7 plantations (25%) not reaching the Regional standard of 150 trees/acre (Table 3). Sugar pine ranged from a minor component to the sole species in a plantation. The amount of Ribes varied between plantations (Table 3). Even though Ribes plants may not have been in the survey plots in some plantations, they were observed in most plantations.

The effect of blister rust on each plantation was examined by determining the stocking reduction due to the disease. It was assumed that all lethally infected trees would die before reaching a merchantable size. Future infections that might occur and further reduce stocking were not considered. Of the 29 plantations, 4 will have their stocking level reduced below minimum acceptable levels (150 trees/acre) by the disease (Table 4). An additional 7 plantations will have their currently unacceptable stocking reduced even further by the disease.

Each plantation was rated for blister rust site hazard based on site and vegetation characteristics. Many of the sites were classified moderate in hazard primarily because of the species of vegetation on the site (Table 2). The vegetation commonly encountered included whitethorn, greenleaf manzanita, and bitter cherry. These species are common associates with Ribes on disturbed sites.

DISCUSSION

Survey results confirm that white pine blister rust is a major limiting factor in the growing of sugar pine in the northern and central Sierra Nevada. Average infection levels of 60 to 70% indicate that sugar pine will not be a significant component in future plantations under existing management direction and activities.

Until the late 1960s it was believed that blister rust would be of minor importance south of US Highway 50. Surveys in 1968 rejected that hypothesis and showed that the rust could become established and intensify in the southern Sierra Nevada. The rate of introduction and intensification would be slow and most infections were expected to be limited to streamsides. Many initial infections in the central and southern Sierra occurred after these surveys in the mid to late 1970s. Intensification of the disease has taken place since then. Although it is not yet 20 years since the scouting surveys, the intensity of the disease and the damage it is causing is greater than anticipated. Even upland sites where the disease was not expected to be a concern are experiencing high levels of infection.

Surveys of natural mixed conifer stands on the Plumas, Tahoe, and Eldorado National Forests in 1969 and 1970 found forest-wide infection levels of 18%, 7%, and 10%, respectively (reference Forest Pest Management Report No. 79-3,

July 1979). Although these two surveys are not directly comparable, they do suggest a large increase in infection over a 15 year period. It does not appear that the rate of infection has stabilized in most areas, either, and further increases may be expected.

It is difficult to say what effect the disease will have on sugar pine management on the Sierra and Sequoia National Forests since they were not surveyed. Plans for these surveys are being made. However, based on surveys of natural stands on these Forests in 1982 and 1983 and the increasing observations of the disease since then, it is anticipated that blister rust may be a limiting factor on sugar pine management in plantations on these Forests.

Plantation age and present level of infection will influence the future of existing plantations. Lethal infections in older plantations (>7 inches dbh) should not increase beyond their present levels. New infections in uninfected trees in these plantations may occur, but they will be non-lethal because of tree size. The lower level of infection in some of these older plantations is a result of limited exposure to the fungus during their early, more susceptible years.

Although some existing older plantations may not be exposed to additional lethal infections by blister rust, present incidences of 40 to 50% in very young plantations suggest that their infection levels may increase considerably. With 10 to 15 years of susceptibility remaining, trees in these plantations will experience several additional infection periods. Most infections will be lethal in trees of this small size. Also, since blister rust is established in these areas, sufficient inoculum will be available for infection to occur regularly even without the influence of "wave years" of infection.

The effect of blister rust on new plantations with sugar pine could be disastrous. Inoculum is present and in sufficient quantity in most areas so as not to be a limiting factor to infection. Environmental and climatic conditions were once considered limitations to infection. Climate is not limiting the southerly spread and intensification of the disease and new plantations throughout the Sierra Nevada will be at greater risk. Environmental factors were thought to influence site hazard potential by favoring rust development in streamside areas and lower north-facing slopes. Although the intensity of infection (number of cankers per tree) may differ between what were classified as high or low hazard sites, infection levels on low hazard sites were found to be sufficient to adversely effect the amount of sugar pine in future stands. The types of sites where sugar pine can be managed at acceptable levels will be limited, if they exist.

A management concern other than the regeneration of sugar pine exists because of blister rust. Plantations with sugar pine are being grown on the National Forests. Many of these will not produce the timber volumes projected at rotation because of the loss of sugar pine to blister rust. A proportion of these will not be adequately stocked. Management activities, such as release and thinning, may be performed in these plantations even though stocking levels may fall below acceptable levels in future years because of blister rust caused mortality. Past release activities were observed in some plantations in this survey that will be non-productive because of the loss of most of the trees in the stands from blister rust. All plantations less than 30 years old where

sugar pine is a necessary component should be carefully examined for blister rust prior to prescribing any activity. Decisions will need to be made on Forests as to what level of stocking will be adequate to retain plantations and when plantations should be replanted.

MANAGEMENT ALTERNATIVES

1. No Action. Continuing present management direction would result in the loss of most of the planted sugar pine. Newly planted stands may become understocked while still in the sapling stage depending on the amount of sugar pine and non-host species planted. Existing younger plantations may also not meet stocking standards as blister rust incidence increases. Management activities in plantations with a significant sugar pine component may not be effective or beneficial with the loss of the sugar pine stocking. The availability of non-rust resistant sugar pine seed in the seed bank would limit the emphasis and opportunities to produce rust resistant seedlings for outplanting.

2. Discontinue Management of Sugar Pine. Direction would state that sugar pine is not a viable species for regeneration and further planting of this species would be discontinued. Existing plantations with sugar pine would be evaluated to determine if sufficient stocking of non-host species is present. If not, these plantations may be interplanted with non-hosts depending on the present and expected effect of blister rust on the existing stocking. Natural regeneration of sugar pine would not be relied upon as advanced regeneration during overstory removals and other partial cuts.

3. Ribes Control. Localized control of Ribes within and in the immediate vicinity of sugar pine plantations has been suggested to decrease the potential of blister rust infection of the pines. Ribes control has had a long history in California. In the early 1970s control efforts were discontinued because of cost. Present suggestions would be to destroy all Ribes plants within designated plantations of sugar pine, including a satisfactory buffer strip around the plantation. The difficulty and expense of mechanically removing plants would probably make this an unlikely possibility. The application of herbicides may be a less expensive technique.

The results of this survey do not support the efficacy of this alternative. Levels of blister rust infection varied without respect to the amount of Ribes in the plantation. However, the amount of Ribes present during the life of a plantation can not be determined by a single occurrence survey such as this one. The presence and amount of Ribes during the first 15 years of a plantation's life is probably more significant from a rust potential standpoint than the later years of the plantation's life. Although a correlation between the average number of infections per tree and the amount of Ribes may be found if additional work were done, mortality of a sugar pine can result from a single infection and any correlation would have little importance from a management perspective.

Other difficulties exist with this alternative. The vast majority of Ribes plants would have to be killed. This would require searching and hand application of herbicide within 1 to 2 years after logging. A second treatment

within 2 years would be necessary to suppress newly germinated seedlings that arise from the disturbance. Periodic treatments would be necessary to maintain a low population level of Ribes for the first 15 to 20 years of the plantation depending on the rate of pine growth. This might require 6 to 8 herbicide applications. Neither economics nor public opinion would likely support such activities. As mentioned above, a buffer strip free of Ribes would be necessary in surrounding stands. Past control efforts found that approximately 1000 feet free of Ribes around stands of sugar pine were required to limit infection by blister rust. This adds considerable areas of treatment required, especially for larger plantations. Additional work needs to be done before this alternative should be considered for application.

4. Overplanting. Non-rust resistant sugar pine would continue to be planted in selected plantations. To assure adequate stocking, non-host species would be planted at levels sufficient to adequately stock the site regardless of the survival of sugar pine. Sugar pine would be planted as additional stock in the hope that some may survive to merchantability. The sugar pine would have to be distributed throughout the plantation during planting to assure that no openings would be present if the sugar pines were lost. Because of the possibility of overstocking, the plantations may require a precommercial thinning after the sugar pine reach a size when they are not subject to mortality prior to becoming merchantable. Because this susceptible stage may last until the trees are at least 8 inches dbh, stand growth may be limited by competition. Non-lethally infected sugar pine could be saved and become part of the managed stand following thinning.

Overplanting non-rust resistant sugar pine as a major component of a plantation has been suggested. With levels of 60 to 70% infection found in plantations during this survey and the possibility of levels increasing, this would require more than doubling the rate of planting of sugar pine to possibly have sufficient stocking. Simple translation of infection levels in this manner to determine required stocking may not be accurate and the loss of a plantation is still considered possible. Also, even if sufficient numbers of trees survived, their distribution in the plantation may result in heavily stocked aggregations surrounded by significant openings.

5. Pruning. Pruning as a control measure of white pine blister rust has been shown to be feasible in certain situations for eastern and western white pines. It may be biologically feasible in limited situations with sugar pine in California. Such a situation would involve a plantation that is sapling to small pole size (4 to 8 inches dbh). The actual time of pruning would need to be determined for each plantation. The objective would be to remove existing branch infections before they have entered the bole. Also, sufficient susceptible tissue in the lower crown would have to be removed to reduce the possibility of new lethal infections forming, meanwhile leaving enough live crown for satisfactory tree growth. The height of needed branch removal would depend on the specific site. Although most infections occur in the lower crown, during this survey lethal infections at 15 to 20 feet above the ground were not uncommon in some plantations.

Rust levels in the northern and central Sierra Nevada will limit future opportunities for pruning in new plantations. Blister rust is becoming established in many areas and is threatening trees from the time of planting. Because lethal infections are common up to at least 10 feet, and 15 years or

more may be required for trees to reach that height, then the probability of multiple infections over time is high. Since sufficient crown must be left on a tree for survival and growth, the opportunity to remove branch infections and additional susceptible tissue in one pruning operation is very limited. The cost of pruning can be considerable and may limit opportunities in most plantations.

6. Site Hazard Rating. Ever since the early days of white pine blister rust research, levels of blister rust infection have been related to various site factors. In California, site hazard was defined during the blister rust control efforts so that the need for control and levels of control of Ribes would be appropriate for the perceived level of rust hazard. A blister rust hazard model and rating system has been developed for western white pine in the interior northwest.

The simplified system that FPM has suggested, which is based on the system used during the days of Ribes control, did not prove accurate during this survey. Rust hazard in the Sierra Nevada cannot be determined using only topographic and vegetation conditions. A strong research effort would be necessary to determine what characteristics can be related to rust potential. This information would then have to be formulated into some type of predictive system for use in the field. Verification in a variety of sites would be necessary. Until such a system is available and usable in California on both natural and disturbed sites, planting non-rust resistant sugar pine on any site will risk infection by blister rust.

Sites are present where blister rust infections are not found. This survey was not able to identify these sites with any accuracy. Some observations that were made suggest that low elevation (<3500 to 4000 feet) sites on upper slopes, either with no aspect or a southerly aspect, may have a low rust hazard potential, at least in the southern end of this survey. These observations need additional evaluation prior to recommending that non-rust resistant sugar pine can be safely planted on any site in California. Because of the limited amount of sugar pine in plantations on these types of sites, natural stands may need to be studied. Care would then need to be taken when translating this information to plantations because of the microclimatic and vegetation changes that occur following logging disturbance.

7. Plant a Minimum Amount of Sugar Pine. Selected sites would be planted with a small proportion of sugar pine grown from the present seed bank inventory. The proportion of sugar pine would not exceed 10 percent. During planting, sugar pine would be thoroughly mixed with other species to assure that it was distributed throughout the site without any clumping. This distribution would be critical because of the probable loss of most of the sugar pine and the need to avoid having holes in the future stand. During any precommercial thinning, sugar pines would have to be examined closely to determine if they were infected. If so, they should be removed from the stand in preference over other non-host species. If uninfected, they can be retained, but it must be remembered that they may still be lost from the future commercial stand if they become infected before they are 7 inches dbh.

Careful site selection may be beneficial in an attempt to reduce the future loss of sugar pine from the stand. Although levels of site hazard could not be determined in this survey, it does not seem appropriate to plant areas with

obviously high probabilities of rust infection with sugar pine. Such areas include along stream bottoms, around meadows and lakes, and in other high moisture areas. Planting in small openings (less than 3 to 5 acres) may also increase the hazard to blister rust because of the slow evaporation of free moisture from foliage and the increased opportunity for infection.

Many of these plantations would have little or no sugar pine at commercial harvest. Satisfactory yields should still be obtained from the non-hosts in the stand. Sugar pines that survive to harvest would provide a greater species mix in stands and reduce the possible effects of other pests. They would also help to maintain a broader pool of sugar pine genotypes in the forest. Survivors would provide some sugar pine volume to mills in future decades as the supply of existing mature trees decreases and the number of replacement trees decreases because of blister rust.

8. Planting Rust Resistant Sugar Pine. Genetic resistance to blister rust has been demonstrated in native stands of sugar pine. One type of resistance is determined by a single major gene. The proportion of the gene pool that carries this gene increases from north to south in the Sierra Nevada.

Attempts to identify rust resistant individuals started in the late 1950s, but efforts did not begin in earnest until the mid 1970s. A screening program has recently been initiated under the management of Tree Improvement personnel at Placerville Nursery. An objective of this program is to examine sugar pine phenotypes collected as seed in natural stands for major gene resistance. Once trees are identified with this trait, then their seed can be collected, stored in the seed bank, and be available for outplanting in the appropriate seed zone and elevation.

As of June 1986, 15.75 pounds of sugar pine seed from rust resistant phenotypes were available in the seed bank at the Placerville Nursery. These seed have been collected by District personnel following screening by either the Institute of Forest Genetics or the Tree Improvement screening program. The seed collections come from four National Forests (Klamath, Sierra, Six Rivers, and Tahoe) and three seed zones (301, 525, and 532). Because these seed come from open-pollinated cones under natural conditions, it is expected that only one parent had the gene for resistance. Approximately one-half of the progeny from each collection, therefore, can be expected to be resistant to the rust. This needs to be taken into account when outplanting these identified rust resistant collections. The number of seedlings planted needs to be increased to assure satisfactory stocking following the loss of non-resistant individuals.

In order for the rust resistance program to be effective and seed to accumulate in the seed bank, three events need to occur. First, potentially resistant sugar pine need to be identified by District personnel and seed collected for screening. Since many cone-bearing sugar pines were not exposed to blister rust during their susceptible period, especially in the central and southern Sierra Nevada, the lack of rust will not be a strong criterion for selection. Other characteristics, such as growth, form, and sexual maturity, should be used at this time to select trees for screening. Second, the rust resistance screening program needs to become fully operational and be able to screen seed that is submitted with little delay. Efforts at accomplishing this are underway. Once individuals are identified as resistant, then District

personnel will need to take actions to protect these individuals. Timber sales and other land disturbing activities may need to be modified so that these trees are not lost. Third, when cone crops are adequate, they should be collected and placed in the seed bank to increase the inventory of resistant seed for future use. Efforts at identifying resistant parents in the field need to continue until sufficient individuals have been identified for each seed zone and elevation.

In addition to collecting open-pollinated seed, Districts may arrange to collect pollen from identified resistant trees and control pollinate other resistant trees. The seed from such controlled pollinations would then be 75% resistant and would not require the same amount of overplanting. As the Region's seed orchards develop, controlled pollination of resistant trees may be possible by Tree Improvement personnel and pollen may be made available to Districts for pollination of sugar pines in the field.

A potential problem with the widespread propagation of sugar pine with single gene resistance has arisen. In the sugar pine outplanting near Happy Camp another race of blister rust has been identified. This race can overcome the single gene resistance and cause tree mortality. At this time, the race has not been found outside of this outplanting site. It is anticipated that this race may appear in other areas as single gene resistance individuals are planted. It is not expected that this will occur rapidly, however, and the planting of these resistant sugar pines remains a viable option for one rotation. Future rotations will need to depend on other forms of resistance, specifically those of a multiple gene nature. Research into this horizontal resistance has begun but needs to be accelerated in order to ensure that future sources of resistance are available.

CONCLUSIONS

Sugar pine has a very limited future as a component of plantations in California without the use of rust resistant stock. Although some survival of wild sugar pine can be expected, the amount will vary between locations, and in almost all plantations the proportion of sugar pine stems at harvest will be small. At the present time, we cannot predict infection levels and tree mortality at various sites over the length of a rotation. Therefore, each planting with sugar pine has to assume the same risk level and expect minimal sugar pine volume at harvest.

We are uncertain of the effect of blister rust on the species composition of future stands that regenerate naturally following partial cuts. Although some resistant trees will regenerate in limited areas, the bulk of the natural regeneration will be susceptible to the fungus. The uncertainty lies in the amount of inoculum produced in such stands and the effect of overstory trees on the epidemiology and infection processes of the disease.

At its present rate of operation, the rust resistance program, including collecting seed, screening seedlings, and building a seed bank inventory, will only minimally meet the need for resistant sugar pine in the future. As time passes, continued harvesting in natural stands will reduce the number of rust resistant candidates for screening, thereby, limiting the ability to increase

the genetic base of resistant stock. This will adversely affect our ability to regenerate sugar pine with single gene resistance, as well as decrease our opportunities to develop multiple gene resistance to an operational level.

Although adopting strategies such as overplanting sugar pine or planting minimal amounts in the hope of having some survival beyond the susceptible stage will allow us to regenerate some sugar pine, the long term survival of the species as a commercial entity will not be assured. Less than 5% survival can be expected over a 70 year rotation for most plantations at infection rates determined for the plantations in this survey, . This equals 2 to 3 trees per acre surviving when sugar pine is a 10% component at planting at a 10 foot spacing. These strategies can provide some continuity of sugar pine management at minimal cost until resistant stock becomes more available. However, the longer the delay until an adequate source of resistant seedlings becomes available, the less area that will be successfully regenerated with sugar pine and the greater will be the reduction in sugar pine harvest in 50 to 100 years.

TABLE 1. CHARACTERISTICS OF PLANTATIONS ON FOUR NATIONAL FORESTS IN THE NORTHERN AND CENTRAL SIERRA NEVADA SURVEYED FOR WHITE PINE BLISTER RUST.

FOREST	DISTRICT	COMPARTMENT/ STAND NO.	AREA (AC)	AGE (YEARS)	ELEVATION (FEET)	ASPECT	SLOPE (%)	TOPOGRAPHY
Plumas	Quincy	Guard Stn. 4	48	26	5500	SW	10	Ridge
Plumas	Oroville	415-6	20	*	5500	S-W	20	Upper
Plumas	Oroville	420-1	5	*	5400	SW	50	Upper
Plumas	Oroville	408-14	20	*	5100	S	10	Ridge
Plumas	LaPorte	16-602	55	22	5300	SE	10	Upper
Plumas	LaPorte	16-71A	8	4	5100	NE	20	Mid
Plumas	LaPorte	22-601	89	4	5500	SE	20	Upper
Tahoe	Downieville	055-24	263	24	4400	S-E	25	Mid
Tahoe	Nevada City	Holden Spr.	172	22	4200	S	0	Upper
Tahoe	Nevada City	500-7	68	16	4700	SE	10	Upper
Tahoe	Nevada City	440-6	57	23	5600	SW	10	Upper
Tahoe	Nevada City	435-001	34	21	6000	S-SE	25	Ridge
Tahoe	Foresthill	295-1	8	6	6300	NE-SW	5	Ridge
Tahoe	Foresthill	200-44	17	6	4000	SE	10	Upper
Tahoe	Foresthill	225-38	19	6	5000	SW	0	Ridge
Eldorado	Georgetown	320-31	42	5	5000	SE	20	Lower
Eldorado	Pacific	503-4	93	19	5500	W	5	Ridge
Eldorado	Pacific	510-11	50	7	5300	SW	10	Ridge
Stanislaus	Calaveras	13-21	3	15	5600	NW	20	Mid
Stanislaus	Calaveras	11-23A	4	7&21	5400	SW	10	Mid
Stanislaus	Calaveras	19-1	123	6	5500	S	10	Mid
Stanislaus	MiWok	114-2048	40	24	6100	SE	10	Mid
Stanislaus	Summit	304-1	8	9	5700	NW	10	Upper
Stanislaus	Summit	313-60	9	7	6500	NW	15	Ridge
Stanislaus	Summit	325-2	10	18	4200	N	20	Mid
Stanislaus	Groveland	5-155	13	10	5700	S	5	Upper
Stanislaus	Groveland	5-51C	7	9	5800	S	10	Upper
Stanislaus	Groveland	3-148	18	10	5800	SW	5	Mid
Stanislaus	Groveland	35-53	19	6	4000	SW	30	Upper

* = Natural regeneration of various ages remaining after overstory removal.

TABLE 2. INFECTION LEVELS (%) OF WHITE PINE BLISTER RUST BY INFECTION RATING CLASS AND SITE HAZARD RATINGS OF PLANTATIONS IN THE NORTHERN AND CENTRAL SIERRA NEVADA.

FOREST	DISTRICT	COMPARTMENT/ STAND NO.	TREES EXAMINED	INFECTION CLASS[a] 0	1	2	3	SITE HAZARD[b]
Plumas	Quincy	Guard Stn. 4	86	12	15	66	7	2
Plumas	Oroville	415-6	135	36	6	58	0	1
Plumas	Oroville	420-1	48	40	4	31	25	2
Plumas	Oroville	408-14	136	22	1	65	12	2
Plumas	LaPorte	16-602	472	47	6	44	3	2
Plumas	LaPorte	16-71A	109	56	0	36	8	3
Plumas	LaPorte	22-601	92	36	0	22	42	1
PLUMAS	FOREST-WIDE		1078	39	5	47	9	
Tahoe	Downieville	055-24	207	15	4	73	7	1
Tahoe	Nevada City	Holden Springs	89	31	12	53	3	1
Tahoe	Nevada City	500-7	74	38	1	61	0	1
Tahoe	Nevada City	440-6	323	23	16	59	2	2
Tahoe	Nevada City	435-001	139	14	1	83	1	2
Tahoe	Foresthill	295-1	97	55	0	45	0	3
Tahoe	Foresthill	200-44	156	42	0	42	16	2
Tahoe	Foresthill	225-38	44	41	0	57	2	1
TAHOE	FOREST-WIDE		1129	28	7	61	5	
Eldorado	Georgetown	320-31	295	40	0	21	38	3
Eldorado	Pacific	503-4	308	22	16	61	1	2
Eldorado	Pacific	510-11	330	27	0	39	35	1
ELDORADO	FOREST-WIDE		933	29	5	41	25	
Stanislaus	Calaveras	13-21	107	20	0	35	46	3
Stanislaus	Calaveras	11-23A	56	16	5	41	38	2
Stanislaus	Calaveras	19-1	100	7	0	75	18	3
Stanislaus	MiWok	114-2048	46	20	0	57	24	3
Stanislaus	Summit	304-1	76	17	0	39	43	3
Stanislaus	Summit	313-60	115	10	2	50	39	2
Stanislaus	Summit	325-2	152	30	20	48	2	2
Stanislaus	Groveland	5-155	175	30	0	70	0	2
Stanislaus	Groveland	5-51C	92	13	1	86	0	2
Stanislaus	Groveland	3-148	134	15	0	84	1	2
Stanislaus	Groveland	35-53	130	100	0	0	0	1
STANISLAUS	FOREST-WIDE		1183	28	3	54	15	
SURVEY-WIDE			4323	31	5	51	13	

[a] 0 = uninfected; 1 = non-lethally infected; 2 = lethally infected; 3 = dead

[b] 1= low hazard; 2 = moderate hazard; 3 = high hazard

TABLE 3. STOCKING LEVELS OF TREES AND RIBES IN PLANTATIONS SURVEYED FOR WHITE PINE BLISTER RUST IN THE NORTHERN AND CENTRAL SIERRA NEVADA.

FOREST	COMPARTMENT/ STAND NO.	TREES/ AC	TREES/ACRE BY SPECIES[a]						
			SP	YP	WF	RF	DF	OTHER	RIBES
Plumas	Guard Stn. 4	173	133	13	27	-	-	-	0
Plumas	415-6	232	56	-	-	176	-	-	0[b]
Plumas	420-1	1120	80	200	740	-	-	100	0[b]
Plumas	408-14	160	32	112	-	16	-	-	32+[b]
Plumas	16-602	204	80	48	12	60	-	4	0[b]
Plumas	16-71A	260	100	-	60	-	100	-	100+
Plumas	22-601	147	20	113	13	-	-	-	0
Tahoe	055-24	110	57	50	3	-	-	-	37
Tahoe	Holden Spr.	80	56	8	8	-	-	8	8[b]
Tahoe	500-7	80	27	27	-	-	-	27	0[b]
Tahoe	440-6	244	89	116	31	-	-	9	0[b]
Tahoe	435-001	234	34	114	80	6	-	-	0[b]
Tahoe	295-1	720	13	160	53	493	-	-	53
Tahoe	200-44	907	93	760	27	-	13	13	80+
Tahoe	225-38	93	-	93	-	-	-	-	80
Eldorado	320-31	1313	47	207	113	-	20	927	93
Eldorado	503-4	233	73	147	-	-	-	13	120
Eldorado	510-11	381	47	320	7	-	-	7	53
Stanislaus	13-21	192	40	-	112	-	-	40	160+
Stanislaus	11-23A	173	13	120	-	-	-	40	107+[b]
Stanislaus	19-1	40	40	-	-	-	-	-	0[b]
Stanislaus	114-2048	320	240	-	80	-	-	-	0[b]
Stanislaus	304-1	227	27	147	40	-	-	13	160+
Stanislaus	313-60	520	27	93	347	13	-	40	107
Stanislaus	325-2	560	90	110	210	-	10	140	10
Stanislaus	5-155	220	140	80	-	-	-	-	0
Stanislaus	5-51C	120	120	-	-	-	-	-	160
Stanislaus	3-148	147	107	40	-	-	-	-	53+
Stanislaus	35-53	193	60	133	-	-	-	-	0

[a] SP = sugar pine; YP = ponderosa and Jeffrey pine; WF = white fir; RF = red fir; DF = Douglas-fir.

[b] Ribes observed in plantation outside of plots.

TABLE 4. PROJECTED SUGAR PINE MORTALITY BASED ON PRESENT INFECTION LEVELS OF WHITE PINE BLISTER RUST AND PROJECTED TOTAL TREE STOCKING FOR PLANTATIONS IN THE NORTHERN AND CENTRAL SIERRA NEVADA.

FOREST	COMPARTMENT/ STAND NO.	TOTAL TREES/AC	PROJECTED SP MORTALITY/AC	PROJECTED STOCKING (T/A)
Plumas	Guard Stn. 4	173	95	78[a]
Plumas	415-6	232	32	200
Plumas	420-1	1120	33	1087
Plumas	408-14	160	23	137[a]
Plumas	16-602	204	37	167
Plumas	16-71A	260	39	221
Plumas	22-601	147	8	139[b]
Tahoe	055-24	110	45	65[b]
Tahoe	Holden Spr.	80	31	49[b]
Tahoe	500-7	80	16	64[b]
Tahoe	440-6	244	54	190
Tahoe	435-001	234	29	205
Tahoe	295-1	720	6	714
Tahoe	200-44	907	47	860
Tahoe	225-38	93	-	93[b]
Eldorado	320-31	1313	16	1297
Eldorado	503-4	233	45	188
Eldorado	510-11	381	28	353
Stanislaus	13-21	192	26	166
Stanislaus	11-23A	173	9	164
Stanislaus	19-1	40	37	3[b]
Stanislaus	114-2048	320	178	142[a]
Stanislaus	304-1	227	19	208
Stanislaus	313-60	520	22	498
Stanislaus	325-2	560	44	516
Stanislaus	5-155	220	98	122[a]
Stanislaus	5-51C	120	103	17[b]
Stanislaus	3-148	147	91	56[b]
Stanislaus	35-53	193	0	193

[a]Plantations where stocking will be reduced below Regionally acceptable levels of 150 trees/ac because of white pine blister rust.
[b]Plantations where stocking is below Regionally acceptable level of 150 trees/ac regardless of white pine blister rust.

FIGURE 1. Infection levels of white pine blister rust in plantations with sugar pine in the northern and central Sierra Nevada.

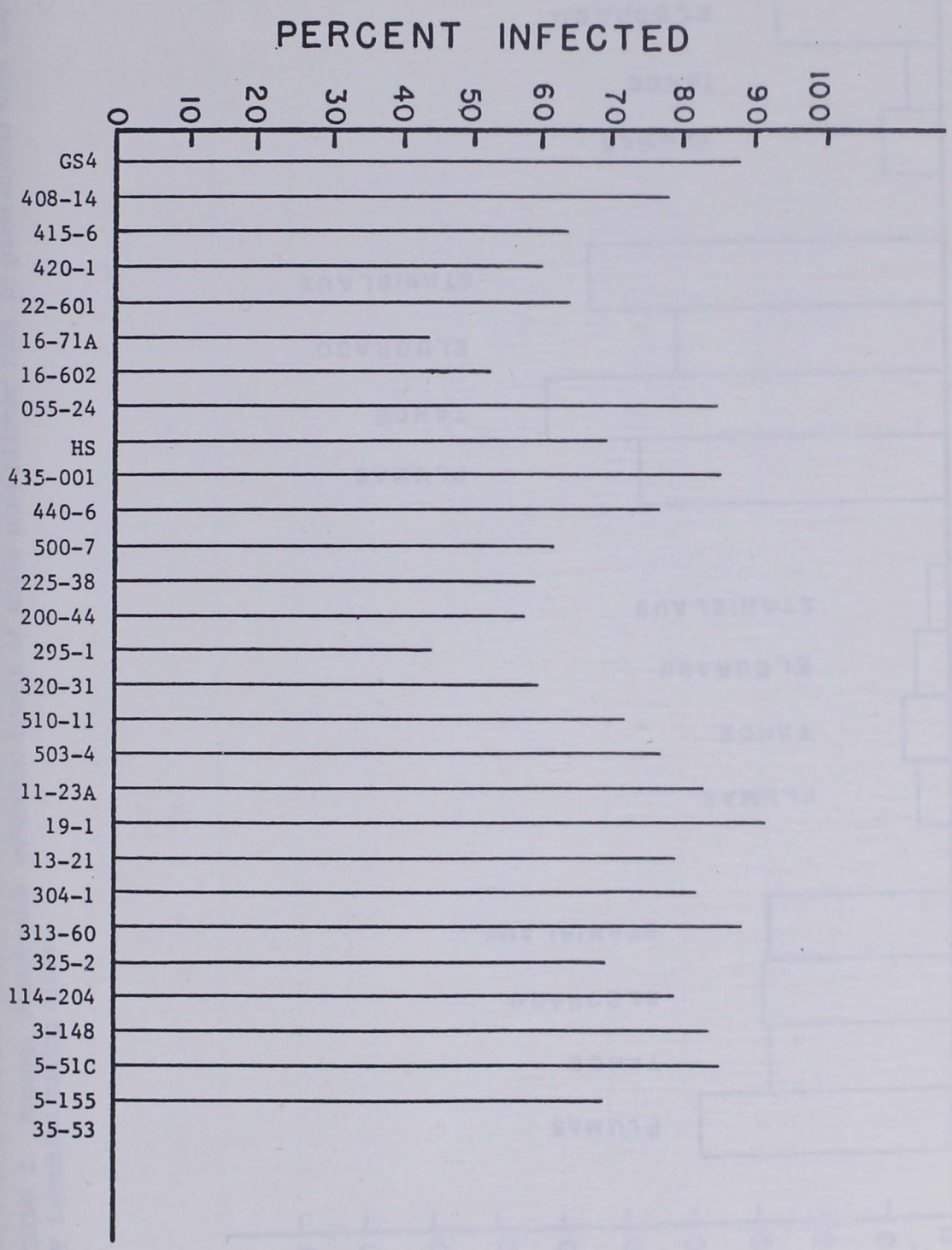

FIGURE 2. Average Forest-wide infection levels of white pine blister rust in plantations with sugar pine by infection rating class.

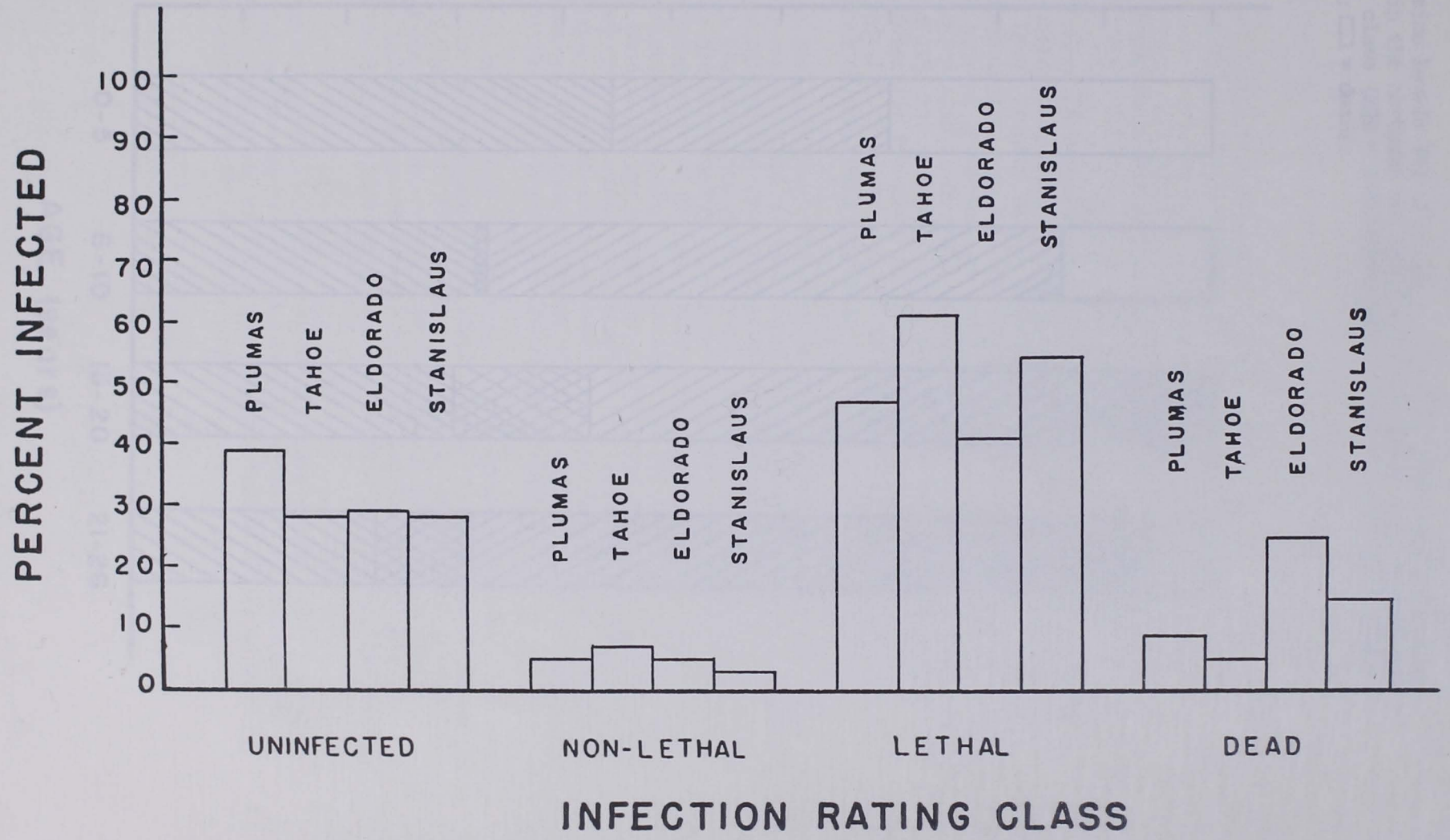

FIGURE 3. Infection levels (%) of white pine blister rust in plantations with sugar pine in the northern and central Sierra Nevada by tree age and infection rating class (▨ = uninfected; ▩ = non-lethal infection; ▩ = lethal infection; □ = dead).